

# **CATHELCO LTD BALLAST WATER MANAGEMENT SYSTEM**

## **PART 4**

### **Section 4.4 Summary of Land-Based Tests**

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#### 4.4.1 Introduction

The land-based tests were conducted at the harbour of the Royal Netherlands Institute for Sea Research (NIOZ), Island of Texel, North Sea. Only natural water sources and naturally occurring organisms were used during the tests. As a consequence, a large variety of different organisms were present in the samples, and their numbers changed rapidly throughout the test season.

The tests were split into two groups:

I. Tests at high salinities / marine conditions. These tests were done with natural water from the NIOZ harbour. Additionally, natural sediments were added to the test water to increase the TSS in some of the tests.

II. Tests at freshwater conditions. These tests were carried out with natural freshwater that has been transported to the NIOZ harbour in a barge (630m<sup>3</sup>), the night before the start of each test run. The water has been collected in the Lake IJssel. During the tests, the water was pumped directly to the NIOZ test installation. Natural sediments were added to the water to further increase the TSS load, in each of the tests.

A summary of the water quality conditions of all land-based tests is presented in the table below:

variable	range	unit
Salinity	0.4 – 36.1	g/kg (PSU)
DOC	2 - 7	mg/L
POC	5 - 36	mg/L
TSS	11 - 86	mg/L
Temperature	9 - 17	°C
UV-T	53 - >62	%
Organisms $\geq 50\mu\text{m}$	109 - 244	X 1000 per m <sup>3</sup>
Organisms $10\leq\mu\text{m}\leq 50$	970 - 1875	Per mL

It was concluded by NIOZ that

[Start Quote] "In conclusion: the CATHELCO UV Ballast Water Treatment System as tested at NIOZ in 2012 is an environmentally safe ballast water management system with a high biological efficacy that generally meets and exceeds the D-2 Ballast Water Performance Standard. [End Quote]

#### 4.4.2 Land-based tests at high salinities / marine conditions

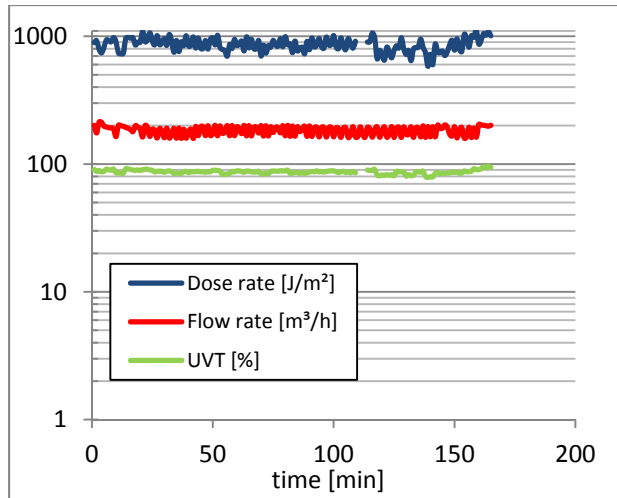
Summary table of the test results for marine water as an extract from the NIOZ report.

Marine water (5 tests)	Test water (T0)		Control (discharge)		Treated (discharge)		unit
	average	min-max	average	min-max	average	min-max	
Organisms $\geq 50\mu\text{m}$	111,000	109,000-113,00	28,000	17,000 – 41,000	4	1 - 9	Per m <sup>3</sup>
Organisms $10\leq\mu\text{m}\leq 50$	1287	968 - 1663	94	58 - 122	3	0 - 6	Per ml
Heterotrophic bacteria	2.2	1.3 – 2.8	1.0	0.9 – 1.2	0.8	0.1 – 0.15	X1,000,000 per ml
E. coli	<10	<10	<10	<10	<10	<10	Cfu/100 ml
Enterococci	1	<1 -2	<1	<1	<1	<1	Cfu/100 ml

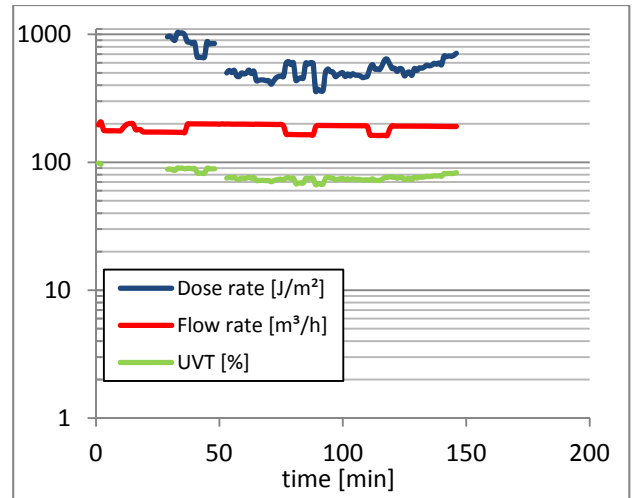
The operational parameters of the system were logged automatically during each of the tests. Averages of salinity, temperature and TSS as well were the operational parameters from the Cathelco BWMS log files during the tests are presented on the following pages. In addition, pressure values in front of the filter and after the filter were recorded from test M3 onwards.

For full biological results see the NIOZ report land based tests (Annex 1d).

**Land-based test M1 - Marine**



UV treatment during uptake of high salinity test M1.

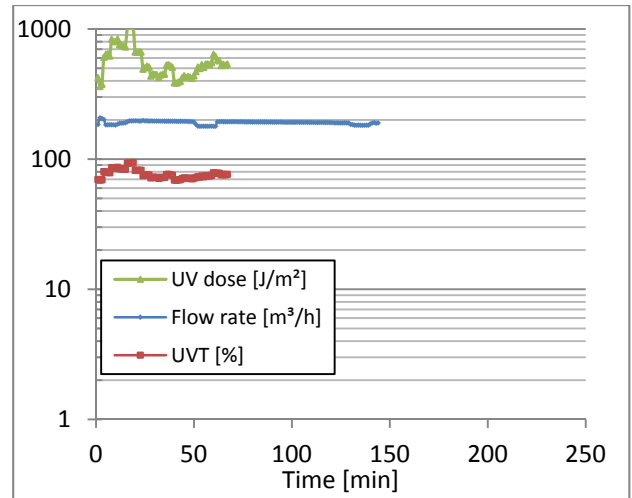
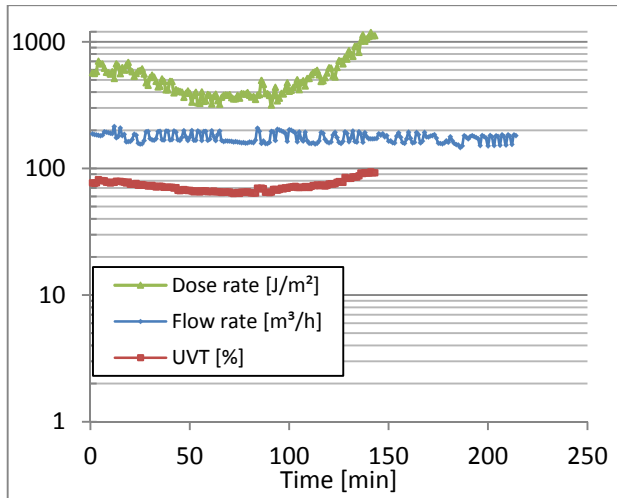


UV treatment during discharge of high salinity test M1.

Averages of salinity, temperature and TSS as well were the operational parameters from Cathelco BWMS log files during test M1. Abundances of organisms > 50µm are included. For full biological results see the NIOZ report land based tests (Annex 1d).

<b>Uptake (T0)</b>	Sal [PSU]	Temp [°C]	TSS [mg/l]	Test water [org./m³]	Org. >50µm [org./m³]	Flow rate [m³/h]	Filter back-flushes	UVT [%]	UV dose [J/m²]	P [KW]	<b>Dis-charge (T5)</b>	Sal [PSU]	Temp [°C]	TSS [mg/l]	Org. >50µm [org./m³]	Flow rate [m³/h]	UVT [%]	UV dose [J/m²]	P [KW]
<b>Control</b>	26,5	8,9	29,2	113000	21566	n/a	n/a	n/a	n/a	n/a	<b>Control</b>	26,7	9	8	32350	n/a	n/a	n/a	n/a
<b>Treated</b>	27,4	8,7	23	n/a	393	183	82	87%	863	32,73	<b>Treated</b>	27,5	8,8	8,3	1	187	77%	584	32,77

**Land-based test M2 - Marine**



UV treatment during uptake of high salinity test M2.

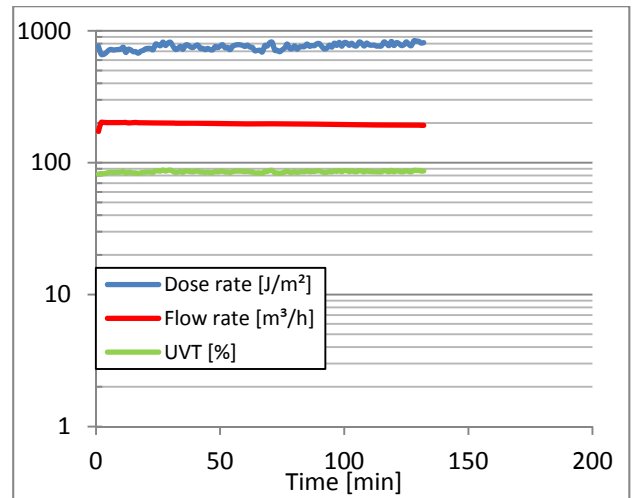
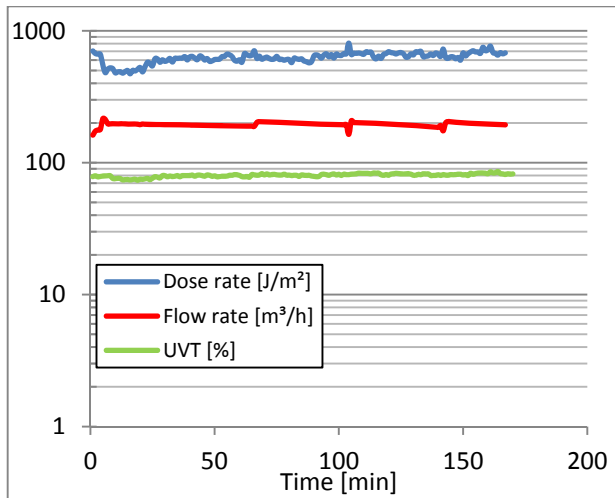
UV treatment during discharge of high salinity test M2.

Averages of salinity, temperature and TSS as well were the operational parameters from Cathelco BWMS log files during test M2. Abundances of organisms > 50µm are included. For full biological results see the NIOZ report land based tests (Annex 1d).

<b>Uptake (T0)</b>	Sal [PSU]	Temp [°C]	TSS [mg/l]	Test water [org./m³]	Org. >50µm [org./m³]	Flow rate [m³/h]	Filter back-flushes	UVT [%]	UV dose [J/m²]	P [KW]	<b>Dis-charge (T5)</b>	Sal [PSU]	Temp [°C]	TSS [mg/l]	Org. >50µm [org./m³]	Flow rate [m³/h]	UVT [%]	UV dose [J/m²]	P [KW]
<b>Control</b>	27,2	9	29,2	113000	21566	n/a	n/a	n/a	n/a	n/a	<b>Control</b>	26,7	9	8	32350	n/a	n/a	n/a	n/a
<b>Treated</b>	27,2	9,2	22,6	n/a	36	175	151	73%	527	30,91	<b>Treated</b>	27,4	9,2	8,5	2,5	191	77%	569	29,87

SUMMARY OF G8 TYPE APPROVAL TEST (Land Based)

**Land-based test M3 - Marine**



UV treatment during uptake of high salinity test M3.

UV treatment during discharge of high salinity test M3.

Averages of salinity, temperature and TSS as well were the operational parameters from Cathelco BWMS log files during test M3. Abundances of organisms > 50µm are included. For full biological results see the NIOZ report land based tests (Annex 1d).

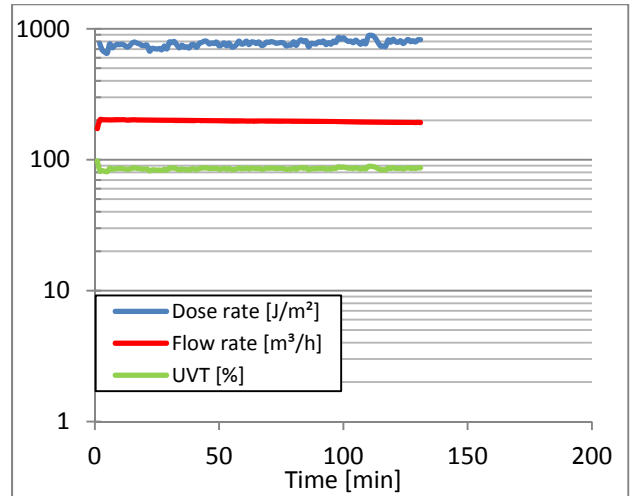
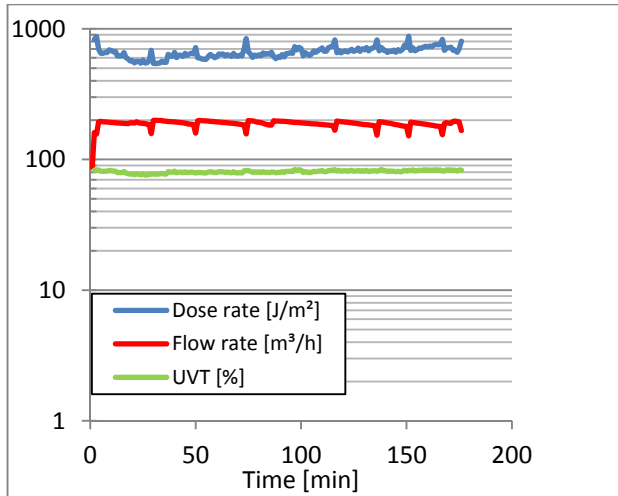
<b>Uptake (T0)</b>	Sal [PSU]	Temp [°C]	TSS [mg/l]	Testwater [org./m³]	Org. >50µm [org./m³]	Flow rate [m³/h]	Filter back-flushes	UVT [%]	UV dose [J/m²]	P [KW]	<b>Dis-charge (T5)</b>	Sal [PSU]	Temp [°C]	TSS [mg/l]	Org. >50µm [org./m³]	Flow rate [m³/h]	UVT [%]	UV dose [J/m²]	P [KW]
<b>Control</b>	31,4	16,3	10,8	108550	46983	n/a	n/a	n/a	n/a	n/a	<b>Control</b>	31,1	15	5,8	40950	n/a	n/a	n/a	n/a
<b>Treated</b>	33,6	16,5	14,2	n/a	51	193	3	80%	634	32,72	<b>Treated</b>	30,5	14,4	5,6	8,7	197	86%	760	32,74



Filter operation during uptake of high salinity test M3. Green - Differential pressure; red - pressure before filter; blue - pressure after filter.

SUMMARY OF G8 TYPE APPROVAL TEST (Land Based)

**Land-based test M4 - Marine**



UV treatment during uptake of high salinity test M4.

UV treatment during discharge of high salinity test M4.

Averages of salinity, temperature and TSS as well were the operational parameters from Cathelco BWMS log files during test M4. Abundances of organisms > 50µm are included. For full biological results see the NIOZ report land based tests (Annex 1d).

Uptake (T0)	Sal [PSU]	Temp [°C]	TSS [mg/l]	Test water [org./m³]	Org. >50µm [org./m³]	Flow rate [m³/h]	Filter back-flushes	UVT [%]	UV dose [J/m²]	P [KW]	Dis-charge (T5)	Sal [PSU]	Temp [°C]	TSS [mg/l]	Org. >50µm [org./m³]	Flow rate [m³/h]	UVT [%]	UV dose [J/m²]	P [KW]
Control	36,1	14,6	14	109250	23800	n/a	n/a	n/a	n/a	n/a	Control	35,8	15,4	4,4	17050	n/a	n/a	n/a	n/a
Treated	36,1	14,9	18,9	n/a	384	188	9	81%	662	32,74	Treated	35,7	15,4	7,3	2	193	86%	773	32,75

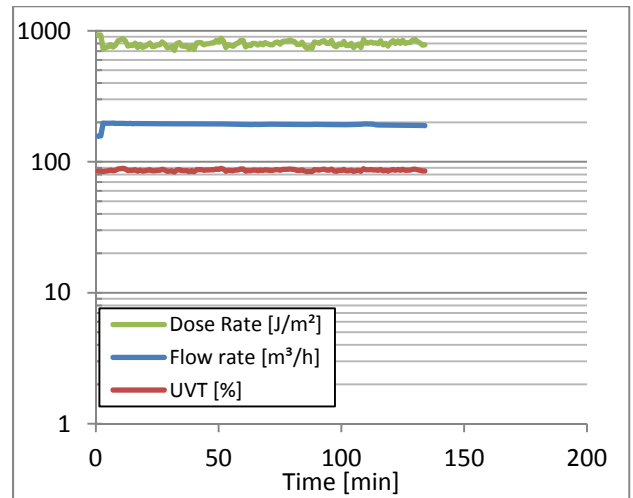
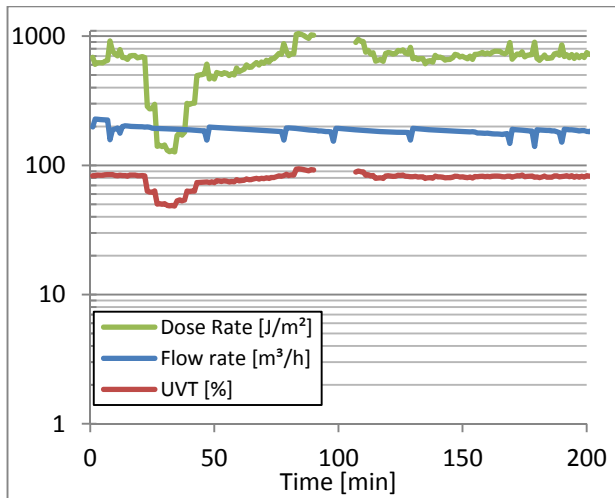


Filter operation during uptake of high salinity test M4. Green - Differential pressure; red - pressure before filter; blue - pressure after filter.



SUMMARY OF G8 TYPE APPROVAL TEST (Land Based)

**Land-based test M5 - Marine**



UV treatment during uptake of high salinity test M5.

UV treatment during discharge of high salinity test M5.

Averages of salinity, temperature and TSS as well were the operational parameters from Cathelco BWMS log files during test M5. Abundances of organisms > 50µm are included. For full biological results see the NIOZ report land based tests (Annex 1d).

Uptake (T0)	Sal [PSU]	Temp [°C]	TSS [mg/l]	Testwater [org./m³]	Org. >50µm [org./m³]	Flow rate [m³/h]	Filter back-flushes	UVT [%]	UV dose [J/m²]	P [KW]	Dis-charge (T5)	Sal [PSU]	Temp [°C]	TSS [mg/l]	Org. >50µm [org./m³]	Flow rate [m³/h]	UVT [%]	UV dose [J/m²]	P [KW]
Control	36,1	14,6	14	109250	23800	n/a	n/a	n/a	n/a	n/a	Control	35,8	15,4	4,4	17050	n/a	n/a	n/a	n/a
Treated	35,8	15,2	9,9	n/a	205	187	8	79%	647	32,73	Treated	35,6	15,7	6,4	6	193	86%	797	32,70



Filter operation during uptake of high salinity test M5. Green - Differential pressure; red - pressure before filter; blue - pressure after filter.

#### 4.4.3 Land-based tests at freshwater conditions

Summary table of the test results for Freshwater as an extract from the NIOZ report.

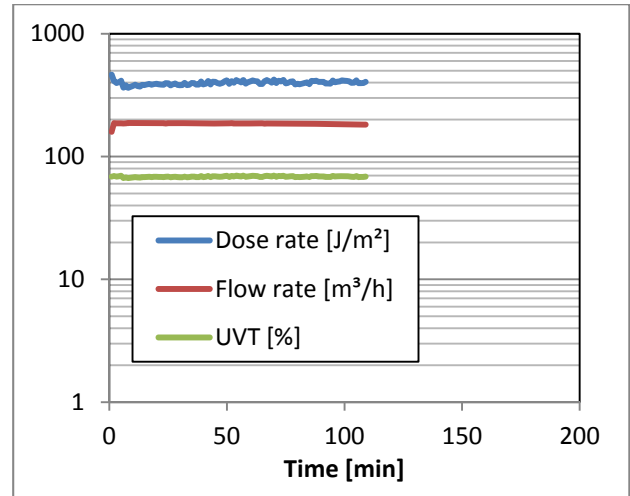
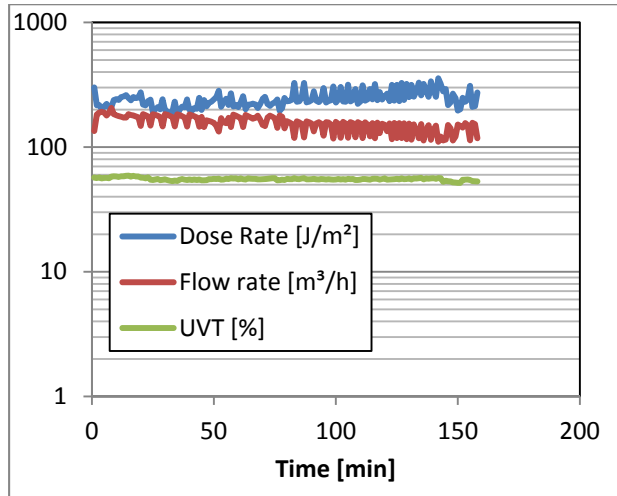
Freshwater (6 tests)	Test water (T0)		Control (discharge)		Treated (discharge)		unit
	average	min-max	average	min-max	average	min-max	
Organisms $\geq 50\mu\text{m}$	169,000	113,000 – 244,000	100,000	36,000 – 371,000	2	0 - 9	Per m <sup>3</sup>
Organisms $10\leq\mu\text{m}\leq 50$	1870	1025 - 1875	172	81 - 381	5	2 - 7	Per ml
Heterotrophic bacteria	19	18 – 20	9	6 – 13	14	7 – 20	X100,000 per ml
E. coli	1200	15 - 3400	300	<10 - 500	<10	<10	Cfu/100 ml
Enterococci	1	<1 - 2	<1	<1	<1	<1	Cfu/100 ml

The operational parameters of the system were logged automatically during each of the tests. Averages of salinity, temperature and TSS as well were the operational parameters from the Cathelco BWMS log files during the tests are presented on the following pages. In addition, pressure values in front of the filter and after the filter were recorded for all of the tests.

For full biological results see the NIOZ report land based tests (Annex 1d).

SUMMARY OF G8 TYPE APPROVAL TEST (Land Based)

**Land-based test F2 - Freshwater**

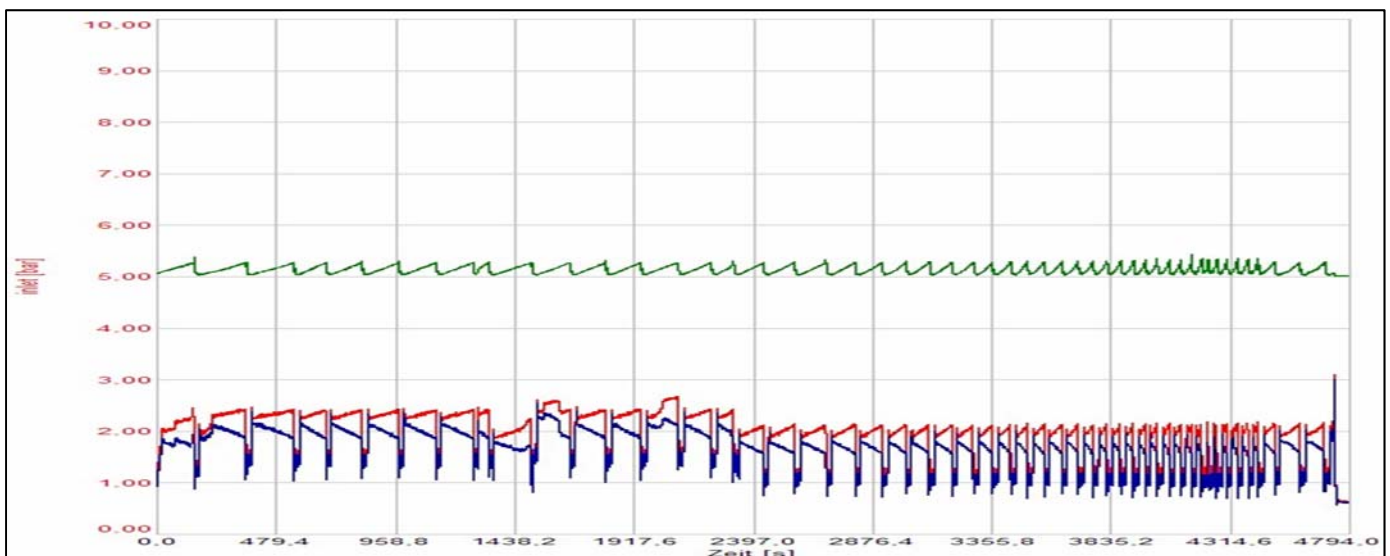


UV treatment during uptake of Freshwater test F2.

UV treatment during discharge of Freshwater test F2.

Averages of salinity, temperature and TSS as well were the operational parameters from Cathelco BWMS log files during test F2. Abundances of organisms > 50µm are included. For full biological results see the NIOZ report land based tests (Annex 1d).

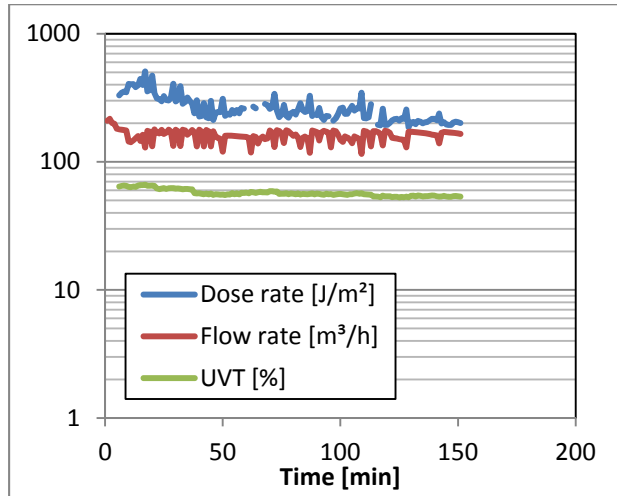
Uptake (T0)	Sal [PSU]	Temp [°C]	TSS [mg/l]	Testwater [org./m³]	Org. >50µm [org./m³]	Flow rate [m³/h]	Filter back-flushes	UVT [%]	UV dose [J/m²]	P [KW]	Dis-charge (T5)	Sal [PSU]	Temp [°C]	TSS [mg/l]	Org. >50µm [org./m³]	Flow rate [m³/h]	UVT [%]	UV dose [J/m²]	P [KW]
Control	0,4	16,3	67,2	243600	329800	n/a	n/a	n/a	n/a	n/a	Control	0,4	16,1	6,4	370900	n/a	n/a	n/a	n/a
Treated	0,4	16,5	53,4	n/a	35	156	50	55%	244	32,74	Treated	0,4	16,5	13,1	23,0	186	69%	399	32,72



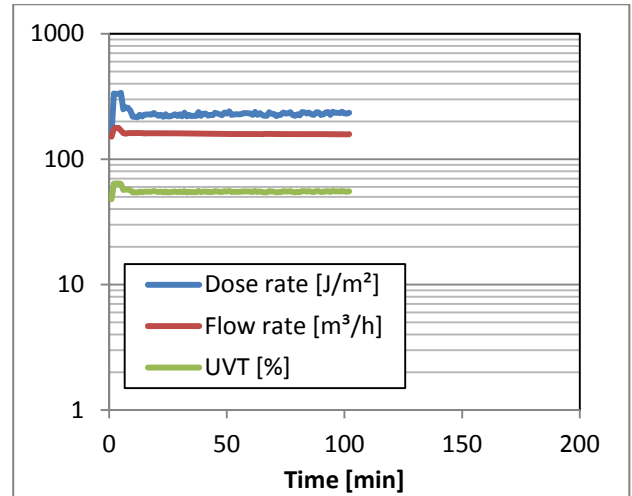
Filter operation during uptake of Freshwater test F2. Green - Differential pressure; red - pressure before filter; blue - pressure after filter.

SUMMARY OF G8 TYPE APPROVAL TEST (Land Based)

**Land-based test F3 - Freshwater**



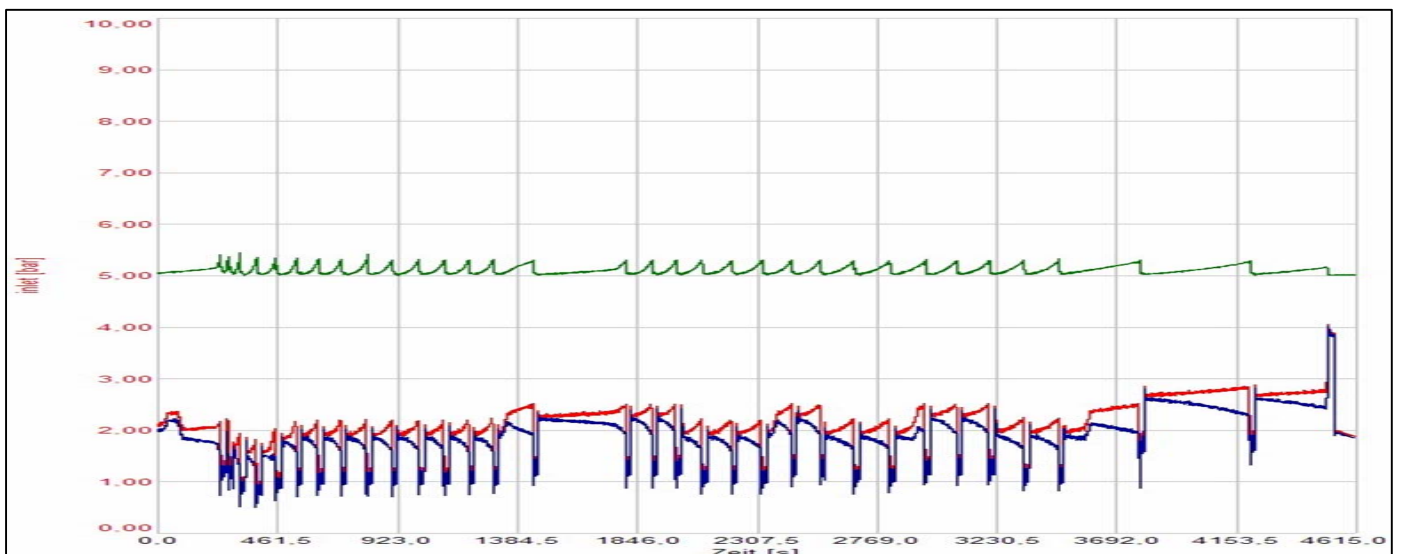
UV treatment during uptake of Freshwater test F3.



UV treatment during discharge of Freshwater test F3.

Averages of salinity, temperature and TSS as well were the operational parameters from Cathelco BWMS log files during test F3. Abundances of organisms > 50µm are included. For full biological results see the NIOZ report land based tests (Annex 1d).

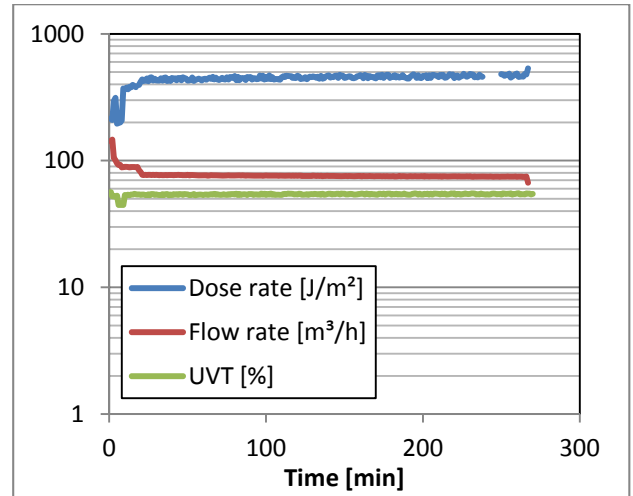
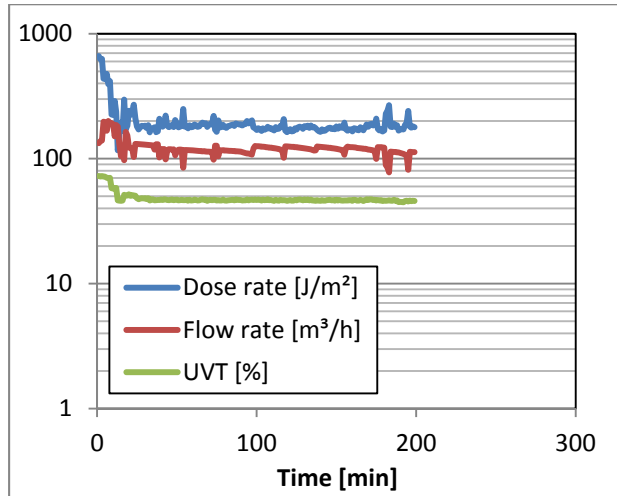
Uptake (T0)	Sal [PSU]	Temp [°C]	TSS [mg/l]	Testwater [org./m³]	Org. >50µm [org./m³]	Flow rate [m³/h]	Filter back-flushes	UVT [%]	UV dose [J/m²]	P [KW]	Dis-charge (T5)	Sal [PSU]	Temp [°C]	TSS [mg/l]	Org. >50µm [org./m³]	Flow rate [m³/h]	UVT [%]	UV dose [J/m²]	P [KW]
Control	0,4	14,6	61,7	200800	207200	n/a	n/a	n/a	n/a	n/a	Control	0,4	14,3	13,7	72100	n/a	n/a	n/a	n/a
Treated	0,4	14,6	52,9	n/a	98	161	33	58%	264	29,35	Treated	0,4	14,5	19	9,0	160	55%	233	32,78



Filter operation during uptake of Freshwater test F3. Green - Differential pressure; red - pressure before filter; blue - pressure after filter.

SUMMARY OF G8 TYPE APPROVAL TEST (Land Based)

**Land-based test F4 - Freshwater**



UV treatment during uptake of Freshwater test F4.

UV treatment during discharge of Freshwater test F4.

Averages of salinity, temperature and TSS as well were the operational parameters from Cathelco BWMS log files during test F4. Abundances of organisms > 50µm are included. For full biological results see the NIOZ report land based tests (Annex 1d).

Uptake (T0)	Sal [PSU]	Temp [°C]	TSS [mg/l]	Testwater [org./m³]	Org. >50µm [org./m³]	Flow rate [m³/h]	Filter back-flushes	UVT [%]	UV dose [J/m²]	P [KW]	Dis-charge (T5)	Sal [PSU]	Temp [°C]	TSS [mg/l]	Org. >50µm [org./m³]	Flow rate [m³/h]	UVT [%]	UV dose [J/m²]	P [KW]
Control	0,4	13,7	69,5	112900	116300	n/a	n/a	n/a	n/a	n/a	Control	0,4	14,6	13,3	36000	n/a	n/a	n/a	n/a
Treated	0,4	13,6	55,5	n/a	46	122	11	48%	198	32,77	Treated	0,4	14,6	19,8	1	77	54	445	29,91

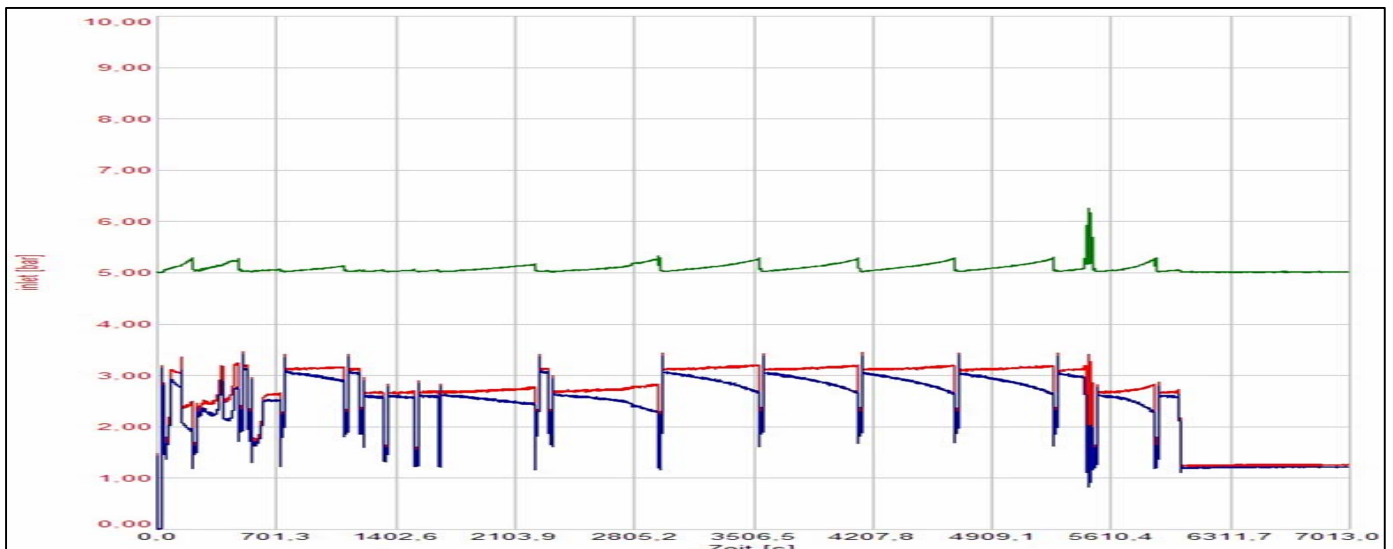
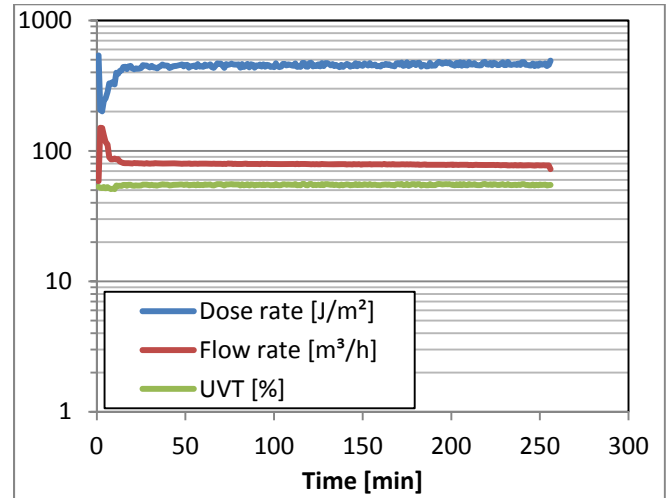
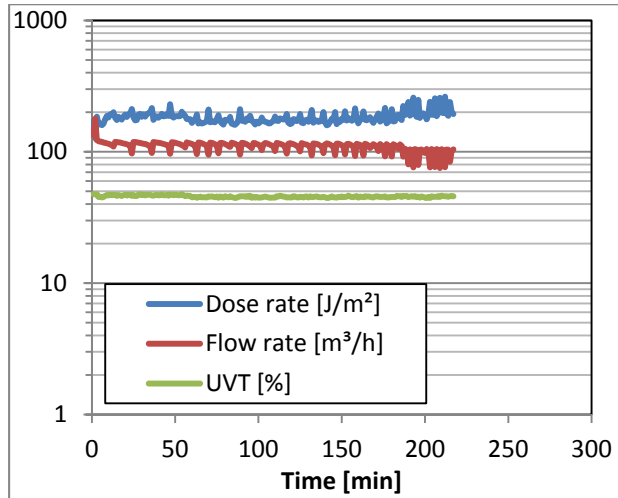


Figure 3: Filter operation during uptake of Freshwater test F4. Green - Differential pressure; red - pressure before filter; blue - pressure after filter.

SUMMARY OF G8 TYPE APPROVAL TEST (Land Based)

**Land-based test F5 - Freshwater**

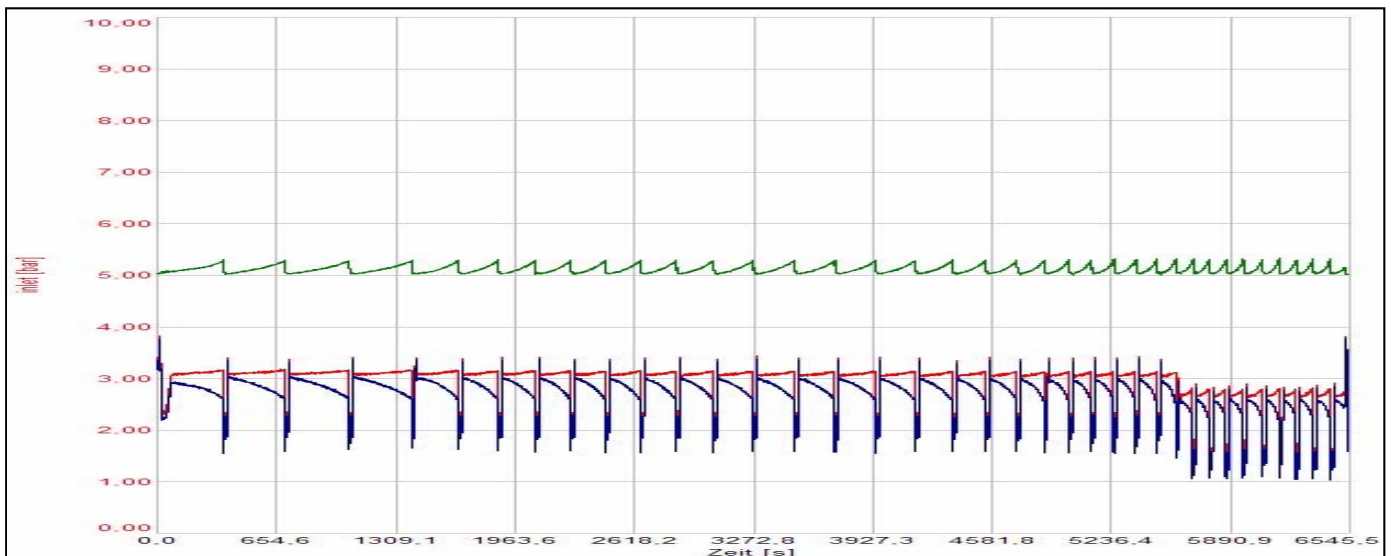


UV treatment during uptake of Freshwater test F5.

UV treatment during discharge of Freshwater test F5.

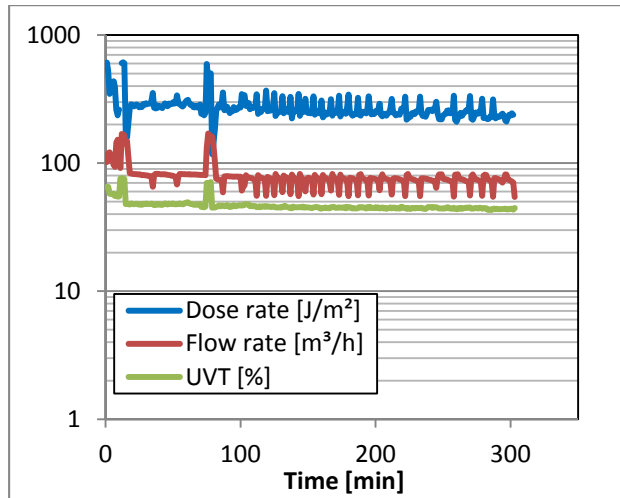
Averages of salinity, temperature and TSS as well were the operational parameters from Cathelco BWMS log files during test F5. Abundances of organisms > 50µm are included. For full biological results see the NIOZ report land based tests (Annex 1d).

Uptake (T0)	Sal [PSU]	Temp [°C]	TSS [mg/l]	Testwater [org./m³]	Org. >50µm [org./m³]	Flow rate [m³/h]	Filter back-flushes	UVT [%]	UV dose [J/m²]	P [KW]	Dis-charge (T5)	Sal [PSU]	Temp [°C]	TSS [mg/l]	Org. >50µm [org./m³]	Flow rate [m³/h]	UVT [%]	UV dose [J/m²]	P [KW]
Control	0,4	13,7	69,5	112900	116300	n/a	n/a	n/a	n/a	n/a	Control	0,4	14,6	13,3	36000	n/a	n/a	n/a	n/a
Treated	0,4	13,7	76,4	n/a	45	110,35	35	46%	183	32,73	Treated	0,5	15,0	16,1	0	80,14	55%	448	32,73

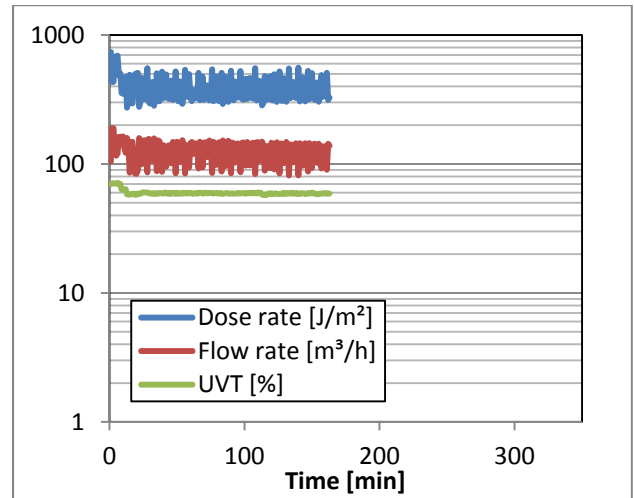


Filter operation during uptake of Freshwater test F5. Green - Differential pressure; red - pressure before filter; blue - pressure after filter.

**Land-based test F6 - Freshwater**



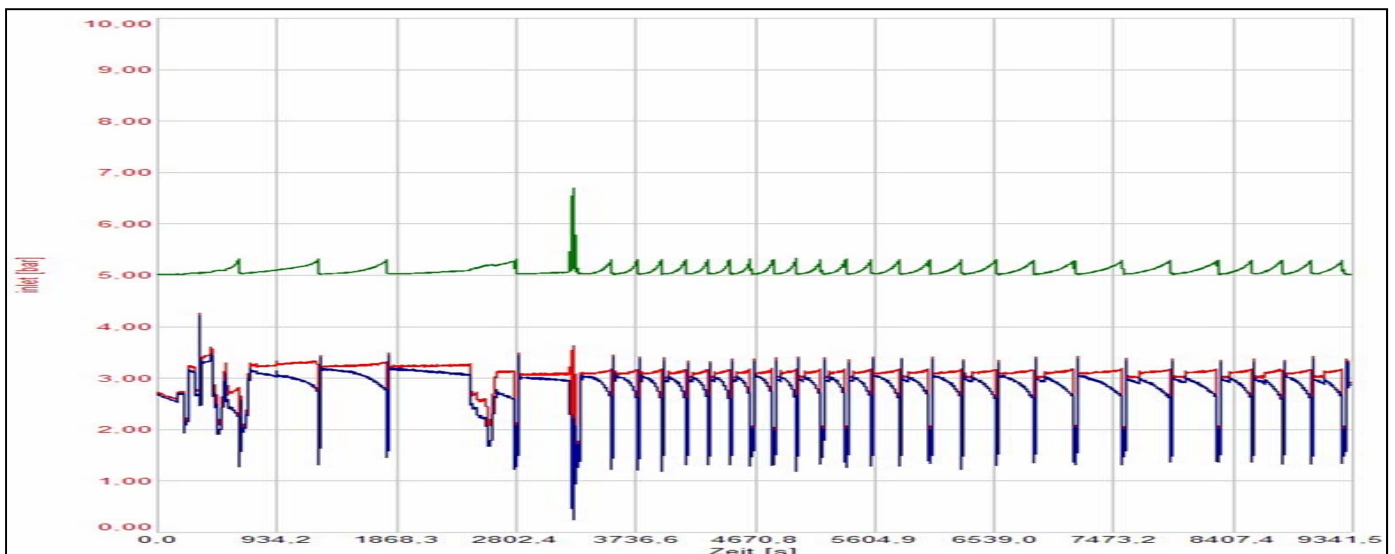
UV treatment during uptake of Freshwater test F6.



UV treatment during discharge of Freshwater test F6.

Averages of salinity, temperature and TSS as well were the operational parameters from Cathelco BWMS log files during test F6. Abundances of organisms > 50µm are included. For full biological results see the NIOZ report land based tests (Annex 1d).

Uptake (T0)	Sal [PSU]	Temp [°C]	TSS [mg/l]	Testwater [org./m³]	Org. >50µm [org./m³]	Flow rate [m³/h]	Filter back-flushes	UVT [%]	UV dose [J/m²]	P [KW]	Dis-charge (T5)	Sal [PSU]	Temp [°C]	TSS [mg/l]	Org. >50µm [org./m³]	Flow rate [m³/h]	UVT [%]	UV dose [J/m²]	P [KW]
Control	0,4	13,3	106,9	172400	130700	n/a	n/a	n/a	n/a	n/a	Control	0,4	12,3	10,9	41400	n/a	n/a	n/a	n/a
Treated	0,4	13,3	59,6	n/a	47	80	30	47%	272	32,76	Treated	0,4	12,7	17,9	1	128	60%	387	32,81

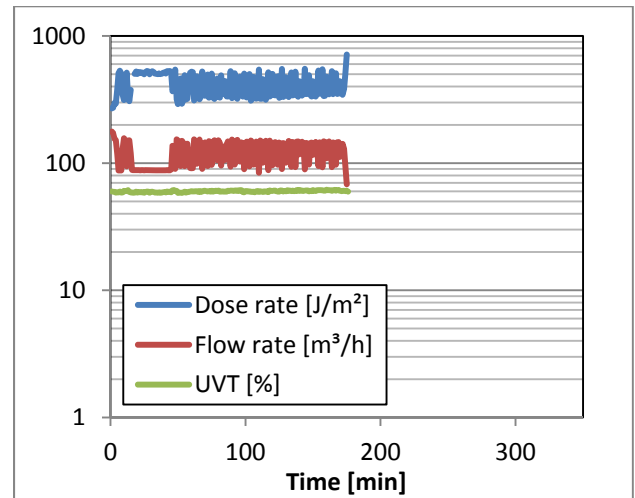
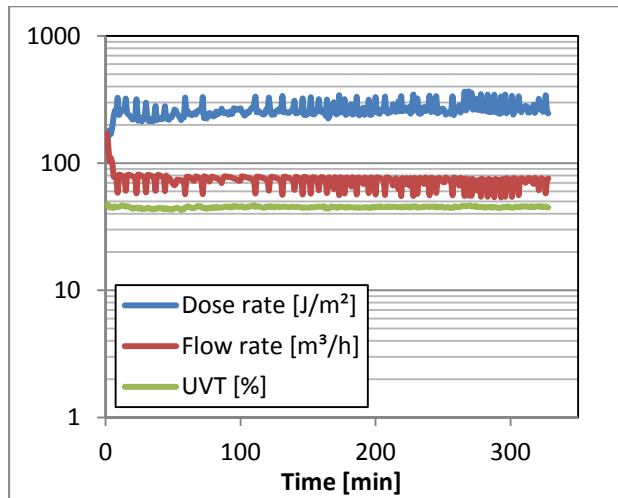


Filter operation during uptake of Freshwater test F6. Green - Differential pressure; red - pressure before filter; blue - pressure after filter.



SUMMARY OF G8 TYPE APPROVAL TEST (Land Based)

**Land-based test F7 - Freshwater**

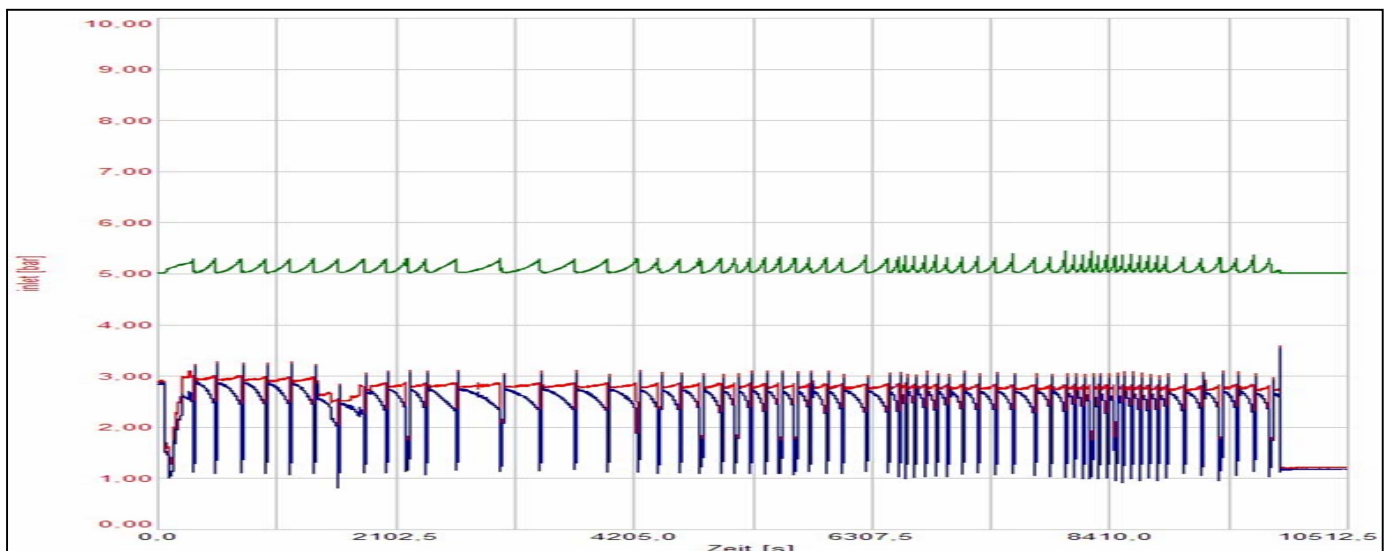


UV treatment during uptake of Freshwater test F7.

UV treatment during discharge of Freshwater test F7.

Averages of salinity, temperature and TSS as well were the operational parameters from Cathelco BWMS log files during test F7. Abundances of organisms > 50µm are included. For full biological results see the NIOZ report land based tests (Annex 1d).

Uptake (T0)	Sal [PSU]	Temp [°C]	TSS [mg/l]	Testwater [org./m³]	Org. >50µm [org./m³]	Flow rate [m³/h]	Filter back-flushes	UVT [%]	UV dose [J/m²]	P [KW]	Dis-charge (T5)	Sal [PSU]	Temp [°C]	TSS [mg/l]	Org. >50µm [org./m³]	Flow rate [m³/h]	UVT [%]	UV dose [J/m²]	P [KW]
Control	0,4	13,3	106,9	172400	130700	n/a	n/a	n/a	n/a	n/a	Control	0,4	12,3	10,9	41400	n/a	n/a	n/a	n/a
Treated	0,4	13,4	63,2	n/a	27	74	62	45%	260	32,73	Treated	0,4	13	19,4	0	121	60%	413	32,00



Filter operation during uptake of Freshwater test F7. Green - Differential pressure; red - pressure before filter; blue - pressure after filter.



END PAGE

Revision	Date	Description	Author	Checked	Approved
04	19/03/2014	Correction due to List of Known Errors	PH	MD	SRE
03	08/01/2014	Summary table on page 4 corrected	MV		
02	04/10/2013	Changed to grammar, correction of title	PH	RF	PH
01	01/10/2013	Changed summary tables	PH		
00	13/09/2013	Initial Issue	MV		